A new late Pleistocene archaeological sequence in South America: the Vale da Pedra Furada (Piauí, Brazil)

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The date of the first settlement of the Americas remains a contentious subject. Previous claims for very early occupation at Pedra Furada in Brazil were not universally accepted (see Meltzer et al. *1994). New work at the rockshelter of Boqueirão da Pedra Furada and at the nearby open-air site of Vale da Pedra Furada have however produced new evidence for human occupation extending back more than 20 000 years. The argument is supported by a series of ^{14}C and OSL dates, and by technical analysis of the stone tool assemblage. The authors conclude that the currently accepted narrative of human settlement in South America will have to be re-thought.*

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The Vale da Pedra Furada site has been excavated in the framework of the Franco-Brazilian mission in Piauí, Brazil. It was discovered in 1998 in a trench dug from the site of Boqueirão da Pedra Furada to more than 100m away (Felice 2000, 2002) (Figures S1 & S2).

Figure S1. Sites of Vale da Pedra Furada and Boqueirão da Pedra Furada.

Figure S2. Site of Vale da Pedra Furada. Opening of the 2000 test excavation and re-opening of the south-east sector. On the left can be seen very large sandstone blocks on the edge of the site.

Materials and methods

1. Taphonomic analysis

The present study is based on the following reasoning. Since the deposition process is the same throughout the sequence at Boqueirão da Pedra Furada (Parenti *et al.* 1996; Parenti 2001), when continuing the excavation below the last archaeological levels, considered at the time by the discoverers as sterile, in theory we should find only natural cobbles and geofacts, and cobbles and flakes. These geofacts were described technically using the same technical criteria used for all other archaeological material from any continent. The material studied comes from two 2 × 1m test pits, 1.5m deep and about 10m apart. The assemblage contains 1424 artefacts, including 1342 cobbles (38% whole, 62% broken) and 82 flakes equally distributed in the two test pits. To describe the broken cobbles, we considered the number of impacts having produced the removals and not the number of removal scars. Indeed, given the micro- or macrocrystalline structure of quartz cobbles, an impact may create several adjacent scars; it is thus preferable to look at 'intentions' followed by effect and not only the effects. According to this criterion, we defined five categories of impact and their technical consequences identified by experimental tests: three unipolar (28% perpendicular to the morphological axis of the cobble, 52% parallel and 17% secant) and two bipolar (6% perpendicular, 1% parallel (Figure S3).

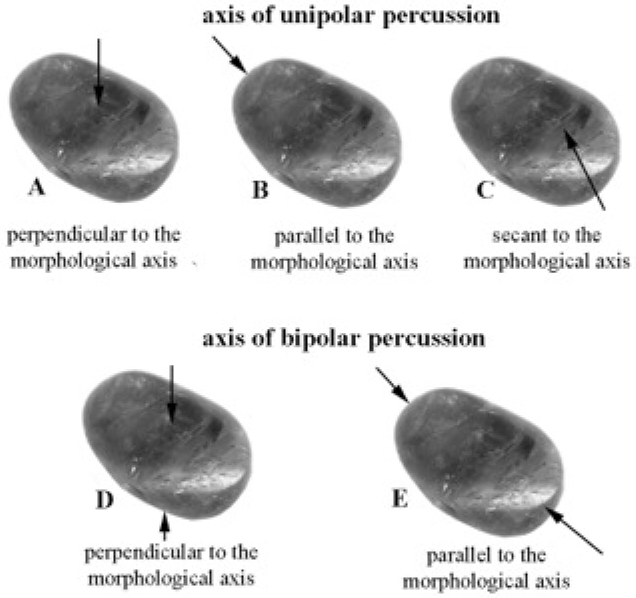

Figure S3. Taphonomic analysis: different categories of impact.

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For archaeological sites, whether Asian, African, European or the sites of Boqueirão da Pedra Furada and Vale da Pedra Furada, only categories C and E are truly used, categories A and B do not exist and category D is extremely rare. The quality of the impact surfaces is another distinctive criterion worthy of analysis. By distinguishing the impact surfaces suitable for the diffusion of energy transmitted by a hammer-stone in the best conditions, i.e. flat or convex and irregular surfaces that increase the points of contact during impact, preventing control of the transmitted energy, we can make the distinction between intentional and natural percussion. Statistical results indicate that in our sample, the quality of the impact surfaces is in near-equal proportions for categories A, D and E and in the majority unfavourable for categories B and C (Table S1). Archaeologically, given that these are technical consequences for removals and/or intended removals themselves, it is difficult to imagine that a knapper would use a random flaking surface without considering its effect! In contrast, under natural conditions, where no intention is involved in the breakage, it is logical to find a balance between these situations. Nature has no functional objectives!

Table S1. Taphonomic analysis: quality of impact points.

Category	Favourable	Unfavourable
A	50%	50%
B	30%	70%
C	41%	59%
D	54%	46%
E	50%	50%

The analysis of the number of impacts affecting the cobbles is also indicative: 82% of the cobbles have only a single effective impact point, 15% have two impact points, 2% have three, 0.6% have four and 0.1% have five. In an archaeological context, most of the active edges require a minimum of three or more impacts, except for some kinds of transversal edges. When to these data we add the contiguousness of the scars when there are more than two impacts, we observe that more than 90% of the scars from each impact are not contiguous, which would be technically aberrant for the creation of an edge where it is the cumulative effect of each removal that is sought. The purpose of the retouch phase is to create a techno-functional unit capable of achieving the intended objectives on the material to be worked.

How does one then make a sidescraper, endscraper, denticulate, point, bec, awl or rostrum?

The analysis continues with examination of the states of the surfaces of removals scars depending on the number of effective impacts (Table S2). Once again, the information shows a difference between natural action and human action since *a priori* when making a working edge there is no sufficient lapse of time to modify a surface state. In other words, an edge is created in a single very short phase. However, if there are different surface states for an impact with effects on another, this would indicate that they were made at different times. In addition, the data shown in Table S2 demonstrate a temporal sequence since the first scars are patinated while the final ones are not.

Table S2. Taphonomic analysis: surface state of removal scars depending on removal order.

		Unpatinated		**Patinated**	
1 impact		433	57%	324	43%
2 impacts	First impact	29	21%	112	79%
	Final impact	130	92%	11	8%
3 impacts	First impact	1	4%	20	96%
	Second impact	4	21%	15	69%
	Final impact	21	100%	0	0%
4 impacts	First impact	0	0%	7	100%
	Second impact	2	28%	5	62%
	Third impact	2	28%	5	62%
	Final impact	7	100%	0	0%

Flakes are uncommon in the sample, due to the micro- and macrocrystalline structure of quartz. Experimentation demonstrates that one should pay particular attention to the surface of the striking platform, the angle between the striking platform and flaking surface, and the energy transmitted to the impact if one wishes to obtain intact flakes. Similarly, one rapidly understands that while one can control the first removal, subsequent removals are clearly more random due to the micro- and macrocrystalline structure of quartz. However, second and third-generation quartzite flakes are possible. Flakes with scars equivalent to retouch are nearly absent, and when they are, such scars are never contiguous. Other criteria can be added, but those discussed here are the most relevant, particularly when examined together.

2. Technical analysis

Areas excavated range from 1 to 5m² depending on sector. At present, 294 artefacts have been recovered from the lower unit (Table S3). Three operational processes have been identified in each archaeological assemblage: one shaping and two knapping.

Table S3. Technical analysis: distribution of artefacts in the lower unit.

Geological unit	Archaeological horizon	No. of artefacts	Area excavated
C3	C3a	6	
	C3b	32	
	C3c	45	
	C3d	71	2m^2
C5	C5a	17	2m^2
C7	C7a	70	5m^2
	C7b	40	1m^2
	C7c	13	1m^2

The shaping process is applied mainly on quartz cobbles and a small number of quartzite cobbles to produce principally unifacial pieces. On these pieces we document a flat natural surface from which the section of the working edge was created using the other adjacent surface. This flat surface, present on nearly all pieces, was one of the selection criteria for cobbles, along with other technical criteria including volume, morphology and the gripping part of the cobble, which was never worked.

The two knapping processes include bipolar reduction *sensu stricto* on quartz cobbles and unipolar reduction. Bipolar reduction *sensu stricto*, depending on cobble volume, enables the production of a variety of flakes. Indeed, as for all knapping modes, predetermination of technical traits for flakes produced by bipolar reduction exists. If the goal is to produce two identical flakes corresponding to half-cobbles, it is sufficient to select a cobble for which thickness is at least three times less than length. Indeed, the thicker the cobble, the greater the force required, increasing the number of accidents that could occur. The production of split cobbles thus reveals an initialisation phase that is based mainly on cobble selection and the quality of the blow applied. If the goal is to obtain a broader variety of flakes, including those termed 'orange slices', the width of the cobble must be larger and the form circular. For the Vale da Pedra Furada artefacts, only split cobbles were produced.

The use of unipolar reduction is probable, but no cores have as yet been found, only flakes that could have been produced by unipolar reduction; these may have been the products of unifacial shaping of tools.

The distribution between unifaces, splits and unipolar flakes in the richest layers differs from one layer to another. In general, the percentage of splits and unipolar flakes is stable, while worked cobbles varies (Figure S4).

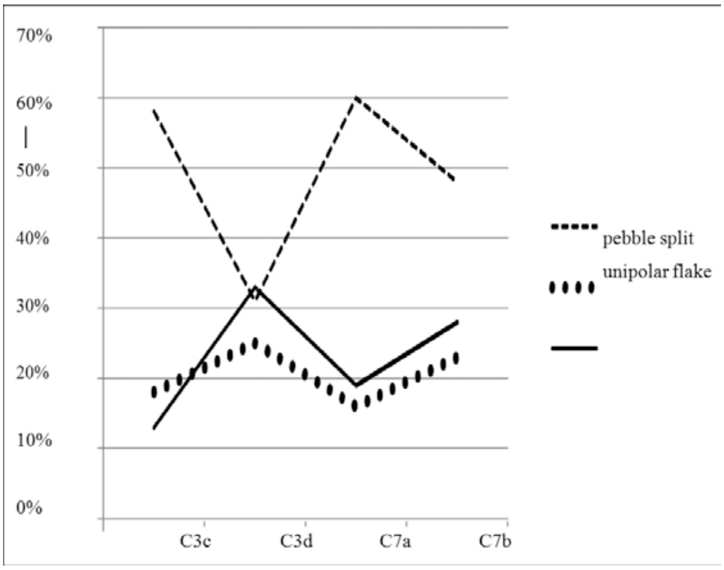

Figure S4. Percentage distribution of the techno-types: worked cobbles, split and unipolar flake (Legend: dashed line: cobbles; dotted line: splits; solid line: unipolar flakes).

When we take this simple distinction between different blank types and identify the retouched parts, we observe a differential distribution (Figure S5). To simplify this presentation, we have grouped the 295 tools into six categories that appear pertinent from one horizon to another. Two categories are only produced on cobbles: spurred beaks (*rostres*) (n=60) and simple or double bevelled distal working edges (n=43). We define a spurred beak as a non- convergent protrusion extending outside the general line of the tool (Figure S6). This protrusion is itself variable with edges that can be rectangular, convex or micro-denticulated, etc. The distal edges have a simple or double bevel with rectangular or concave delineations (main article Figure 4, Figure S7)

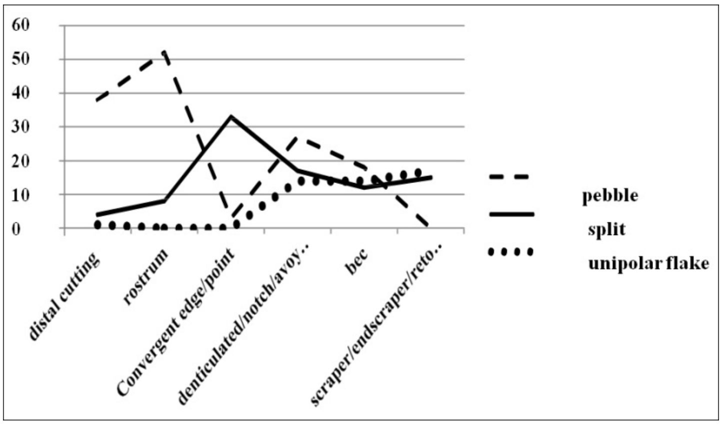

Figure S5. Distribution of tool categories according to blank techno-types (legend: dashed line: cobbles; dotted line: splits; solid line: unipolar flakes).

When we attempt to techno-typologically differentiate the assemblages layer by layer, we see characteristics specific to each layer. Two are cited here. The first involves the choice of cobbles to make spurred beaks. The 16 spurred beaks in the horizon are all made on cobbles weighing between 30 and 50g, while in the underlying layer for the same number of pieces weight ranges between 30 and 200g. The second concerns the variability in cobble weight depending on tool type within a single layer. In layer 7a, tools with distal edges on cobbles range between 5 and 250g while spurred beaks range between 30 and 50g.

The third category of asymmetric convergent pieces (n=36) is primarily made on quartz and quartzite cobble splits (main paper Figure 5). The longest edge is systematically macro-denticulate. In reality, nearly no artefacts are symmetric with linear working edges. This absence suggests the use of other materials—wood or hard animal material—used to make convergent artefacts like points. Lithic tools, as the results of functional analysis indicate, would have been used to work these other raw materials.

Categories 4 and 5, grouping denticulates, notches and becs, are produced on cobbles (39%) and all kinds of flakes (71%), of which the majority are Siret flakes (Figures S8 & S9). These are actually half-flakes that are accidents produced by uncontrolled knapping. The fracture

Figure S6. Rostre. Nos.1 and 2, layer 5a; no. 3, layer 3d, nos. 4, 5 and 6, layer 7a.

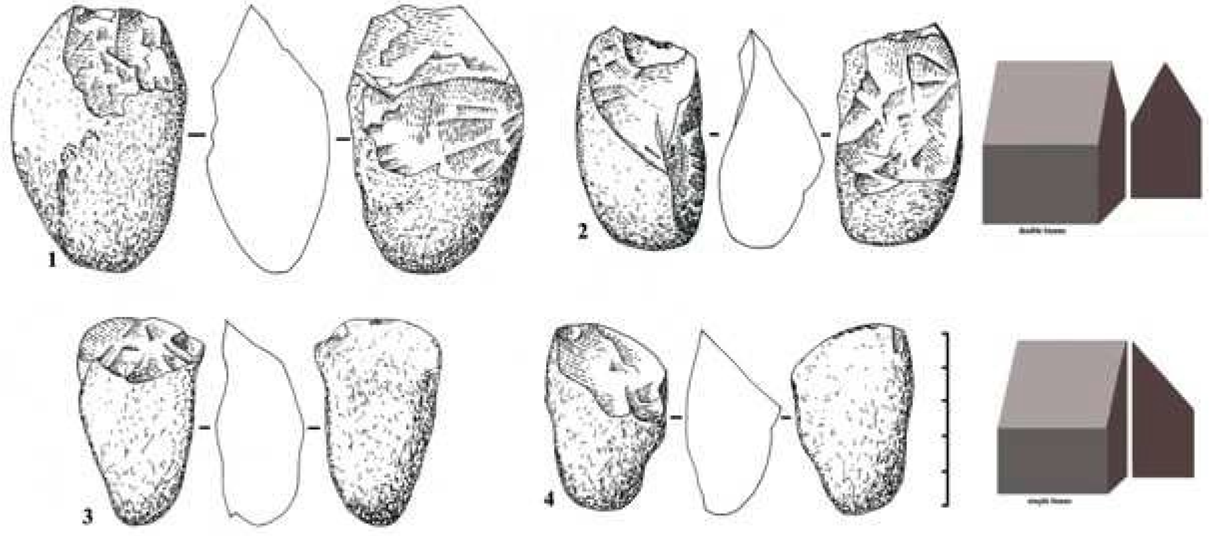

Figure S7. Transversal edges: double bevel, nos. 1 and 2, couche 7a; simple bevel, no. 3, layer 7a, and no. 4, layer 7c.

plane during impact is equivalent to a back, but this trait is not necessarily intentional. Unipolar flakes are mainly cortical and very few have several uni- or multi-directional scars. When they do, these are flakes with very thick platforms avoiding the microfractures caused by the first impact. The difference in blank choice for a single tool category appears to be explained by different functional criteria. For example, notches are made mainly on flakes while denticulates are made on flakes or cobbles depending on the size of the denticulation and are much larger than the spurred beaks. We thus understand that it is necessary to go further in the differentiation of tools and to mistrust the categorisation that tends to create artificial groups. Becs are made on very specific modules regardless of support.

Figure S8. Inverse retouch and bec on split, no. 1, layer 7a. Denticulates on Siret flakes, no. 2, layer 3d and no. 3, layer 7a. Multi-notches on split, no. 4, layer 5a. Symmetric convergent pieces, no. 5, layer 3d. Endscraper, no. 6, layer 3d.

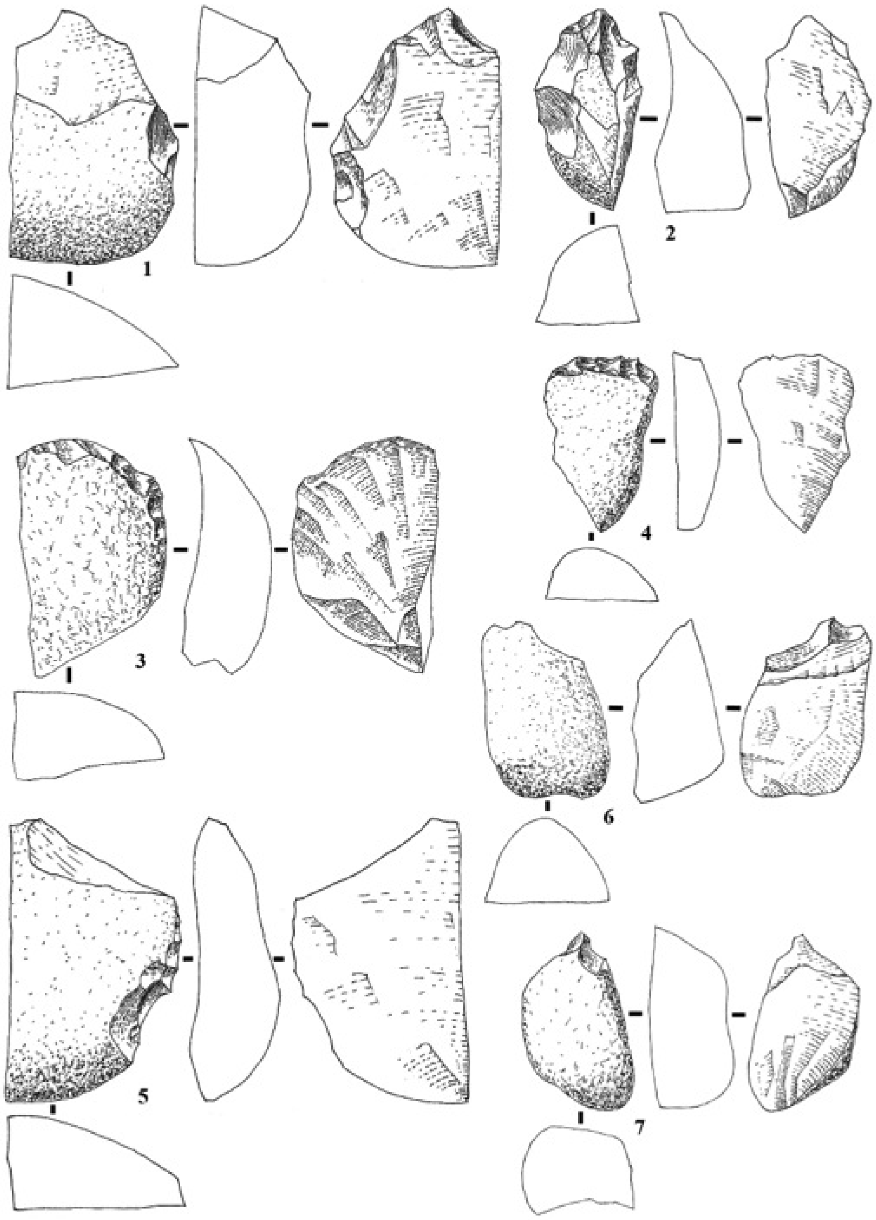

Figure S9. Asymmetric convergent pieces on split with a Siret accident, no. 1 layer 7b and no. 2, layer 3b Siret. Endscrapers on unipolar flake, no. 4, layer C3c, with a Siret accident, no. 3, layer 3c. Denticulate on unipolar flake, no. 5, layer 7a. Becs on split, no. 6, layer 7c and no. 7, layer 7a.

The final category of sidescrapers and endscrapers indicates exclusive selection of flake blanks, which can be explained by needs related to gripping, motion and specific functional traits (Figures S8 & S9).

These data on flakes and flake tools can be compared with the data from the taphonomic analysis. At Vale da Pedra Furada, 47% of the tools were made *versus* 91% in the taphonomic analysis. This indicates that at least 9% of the flakes present are not tools, while 53% are present at Vale da Pedra Furada. Such a difference could be explained at Vale da Pedra Furada only by torrential sedimentary events, which is not the case.

3. Functional analysis

Functional analysis is one of the analytic and scientific tools developed in archaeology. It serves to determine how prehistoric tools were used and for what purpose (Semenov 1964). This method, based on experimentation, allows us to analyse tools made on different raw materials and from all chronological periods (Keeley 1980; Keeley & Toth 1983; Clemente-Conte 1997).

A Leica MZ16 A stereomicroscope, a Leica DM 2500 M metallurgical upright microscope and an Olympus BH50 metallurgical upright microscope equipped with Nomarski prisms, enabling a better view of the quartz surfaces, were used. We also used a scanning electron microscope (ESEM FEI Quanta 600, equipped with an EDX-EXL II System Link Analytical Oxford microanalytical instrument) to observe in detail two tools from layer C3d and on which we identified probable residues. Determination of use-wear on these human-produced artefacts from Vale da Pedra Furada was done by following the parameters defined during preceding studies of quartz (Knutsson 1988; Sussman 1988), and by referring to our own databases of quartz and other heterogeneous rocks such as rhyolite and quartzite (Clemente-Conte 1997; Clemente-Conte & Gibaja-Bao 2009).

Good preservation of artefacts, without taphonomic alteration, can be seen in the archaeological assemblages from layers C3 and C7, making this study possible. Knives and sidescrapers/endscrapers were made on small quartz cobbles, mainly broken by bipolar on anvil percussion. As in many hunter-gatherer groups, the tools were made essentially to work animal and vegetal materials. Retouch on tools in some cases was done to sharpen the edge, for example on the knives. In other cases, it was done to create a more abrupt and resistant edge to work harder materials using transversal motion, such as for scraping and planing.

In horizon C7b, tools were identified that were used for butchery activities with cutting movements (C7b, pieces no. 198038 and 198057) (main article Figure 6), or with a striking motion associated with cutting, allowing the different animal parts to be separated (C7a, piece no. 191381; Figure S8, no. 1). Cutting/sawing activities (C7b, piece no. 198051) and scraping (C7a, piece no. 191299; Figure S8, no. 3) on medium-hard materials such as wood were also identified.

In horizon C3d, two activities differing from the above were also identified. One tool (191388) has traces of use on the right and distal edges. These edges, both retouched, were used for scraping on soft to medium animal material (such as hide), with a very high, nearly vertical working angle because the traces are mainly found on the retouched zone. The other documented activity on another tool is perforation of hard animal material (Figure S10) (191306). This tool has a pointed apical part with rounding and bidirectional microfractures, indicating rotational and bidirectional movements. The convergent edges have strong scalar splintering, produced by the removal of microflakes at different times during contact with the hard material. Only the dorsal crest of the tool shows macroscopic rounding, on which the presence of shiny micropolish, compact and with crackling, was noted. These characteristics were obtained on micropolishes obtained experimentally when working hard animal materials (bone and/or antler).

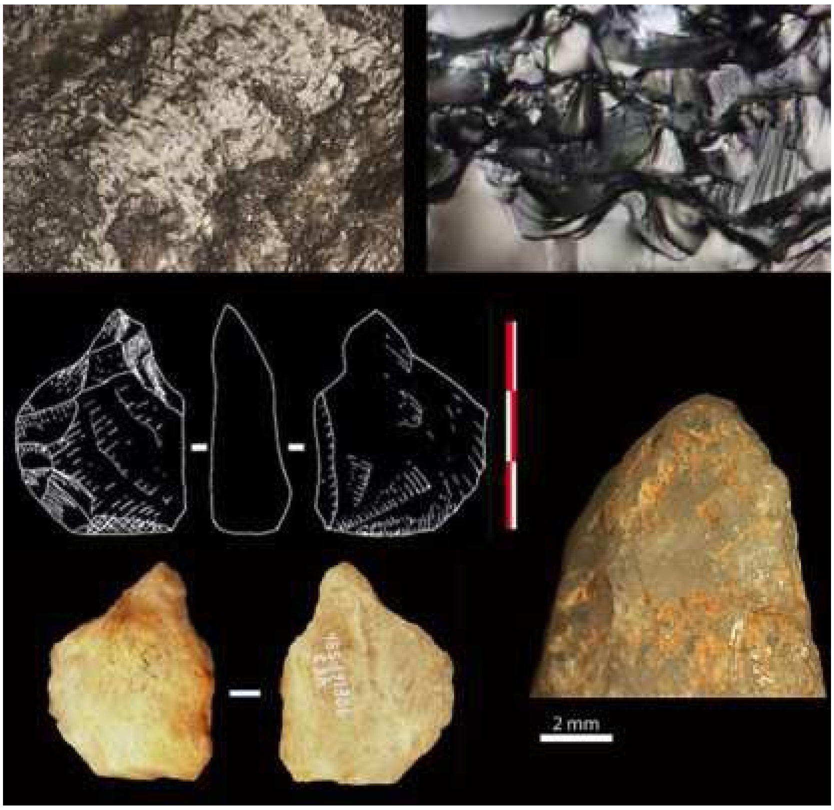

Figure S10. C3d. no. 191306, perforation of hard animal material.

Beneath the reddish sediment residues, we noted the presence of whitish patches that could come from the material worked (Figure S11 C). This tool was thus analysed with a scanning electron microscope to document and identify its chemical composition.

Although the tool had been washed several times with alcohol during microscopic observation, then with an ultrasonic bath with distilled water before the SEM, we were able to observe that small fragments of the white patches were preserved in the splinter depressions on the active edge (Figure S11 B). Two of these patches were analysed to identify the chemical composition and to compare them to the sediment residues. As can be seen in the chemical composition diagrams, silica, coming from the crystalline surface of quartz, is the most abundant element and common to all analyses carried out. However, we also note a difference in the composition depending on the sample analysed. Sediment residues contain the highest percentages of aluminium (Al), titanium (Ti) and iron (Fe), which may be covered by other more organic residues such as potassium (K), calcium (Ca) and phosphorus (P) (Figure S11 A). The other samples analysed by SEM come from residues located on the active edge of the *perçoir*. One of these, identified by the number 2, contains the same chemical components as the preceding sample, although percentages vary. For example, aluminium decreases significantly while peaks for calcium and phosphorus are accentuated and rates for titanium and iron from the sediment remain constant (Figure S11 C). The other residue analysed (Figure S11 B) appears to have been less contaminated by the sediments: titanium is absent and iron low. Aluminium has also decreased significantly and we note the presence of potassium.

5. Are the artefacts 'archaic'?

We return to the criticism that has been published or heard many times concerning the 'archaic' nature of the Piauí artefacts. Made on quartz, these objects do not correspond to the view of modern humans conquering an entire continent; in other word, to the view that we have of cognitive and aesthetic capacities. This posture readily explains the fact that these lithic pieces have been relegated in the scientific literature to the rank of geofacts, since sophisticated lithic and bone industries are known in Eurasia. This view is the reflection of a 'fantasised' history of *Homo sapiens* constructed in the twentieth century in relation to Neanderthals: a dialetic that would fuel the debates of learned societies and continues to shed much ink even today! Neanderthals *versus* modern *H. sapiens* or the history of one human population overcome by the progress of another, or that of a human population conquered by superior technology.

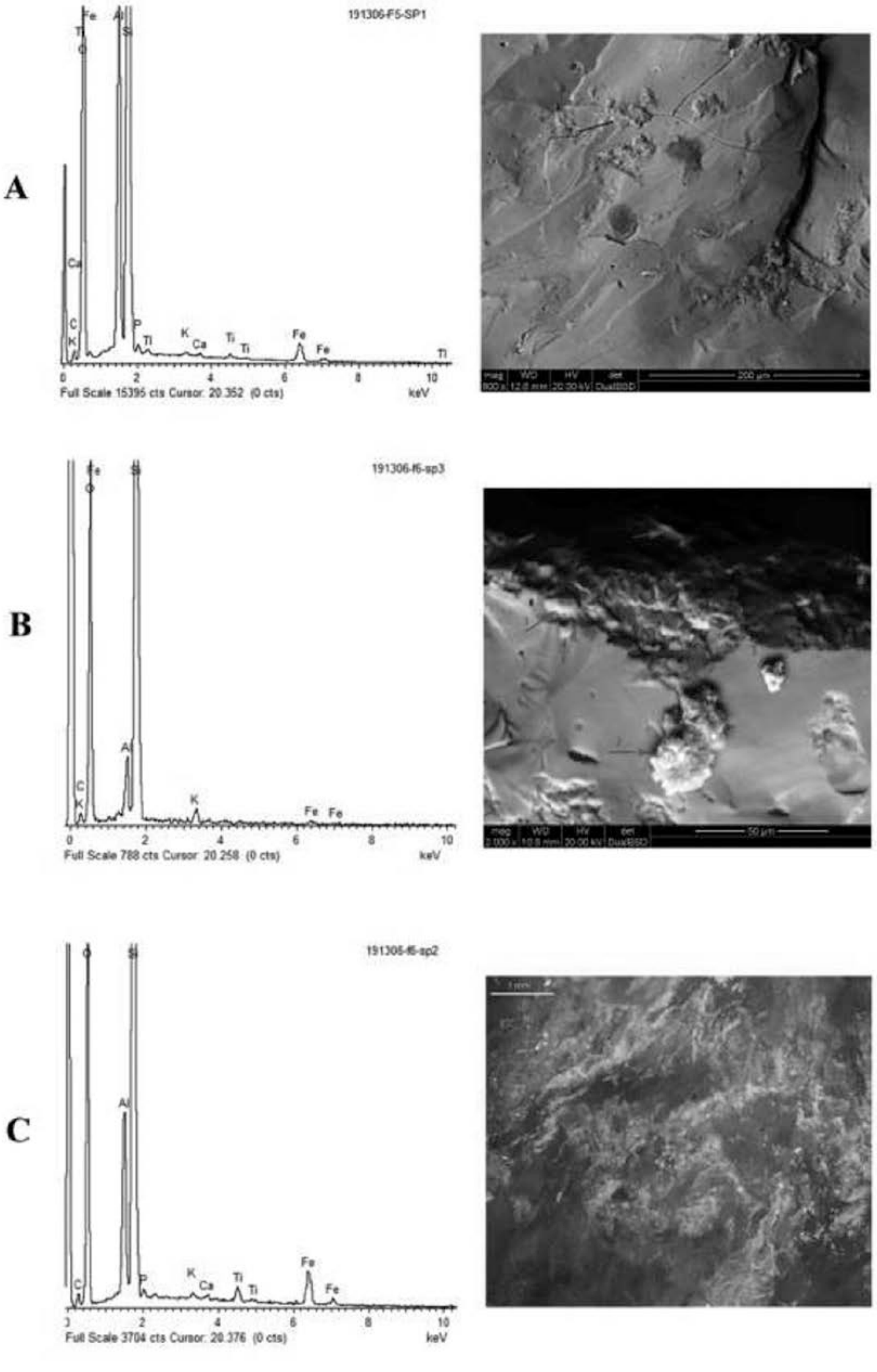

Figure S11. C3d. n°91306. Chemical composition of the residue on the piece, analyzed by scanning electron microscope.

This dual history was then transplanted to the east, to see *H. sapiens* conquer the entire planet due to revolutionary and unequalled technology. In a way this view explains the attachment to the Clovis industries in North America, these armatures being direct evidence of sophisticated hunting weapons and thus of a conquering, dominant and migrating technology.

For we who are technologists, it is clear that one cannot use a purely morphological approach to artefact analysis that is entirely external to the artefact. The archaic nature is only the reflection of a lack of technological comprehension of the artefact. In the first place, we refer to contradictions in the documentation treating the Final Pleistocene industries in Indochina, southern China and Korea that are generally made on cobbles (unifacial shaping, bipolar and unipolar reduction) and made by modern humans, industries that are not considered archaic (Boëda 2013).

Yet it is a second more interesting point that should be stressed because this criticism considers the small role given to technological analyses. If we briefly examine why there was such a preference for cobbles in East Asia, we can imagine that this choice has nothing to do with primitiveness, but rather corresponds to a technical path that has its own evolution with specific advantages, constraints and motions. The archaic nature is expressed when the operatory scheme is seen as very short in terms of motions. In other words, the longer the initialisation phase of a core or shaped piece, the more we see the evolved nature of the process. But one forgets that the initialisation phase is only a means and not an end in itself. Its objective is to configure a block prior to removal of predetermined removals or the shaped piece prior to use. And to do so we have two distinct or associated methods: selection and preparation. Given that technological analyses are rarely done, the selection phase passes entirely unnoticed, although it is crucial when reducing cobbles. Bipolar reduction to obtain splits is the quintessence of technical intelligence, since there is no waste and the mass of the cobble provides two entirely predetermined removals.

We change our angle of analysis and focus now on the definition of a tool and how it can be analysed. In a techno-functional analysis, a tool is divided into three distinct parts: a transformative part, a prehensile part generally receiving the energy, and an intermediate part that transmits this energy. Turning to the prehensile part, as is the case for nearly all unifacial industries, the choice to grip a natural prehensile part reflects a specific technical intention. This is a structuring concept of the tool completely opposed to flaked tools. By deconstructing each tool into a prehensile part and a transformative part, we see immediately that for cobble selection, the prehensile part is considered at the moment of selection and is ready to function. Preparation is needed only on the transformative part, with a broad range of diversity. Yet for tools on knapped flakes, it is the active transformative part that is created 'naturally' during reduction. The prehensile part will be more diverse depending on the operatory scheme used. In other words, depending on the degree of predetermination of removals, the prehensile part on flakes may or may not be determined in advance. And it is during the evolution of knapping production modes that we see standardisation of the prehensile part, as in Levallois, blade and bipolar production *sensu stricto*, standardisation that is related to the concept of hafting. The shaping option for cobbles does not have this evolutionary dimension, at least for its prehensile part since this is selected prior to shaping and thus remains unchanged. Such invariance will persist until tools are produced on flakes. In other words, the path for worked cobbles is condemned to not evolve in the direction of the type of energy used and its transfer. The concept of hafting is *a priori* contradictory with a prehensile part of this kind. If evolution occurs, it would affect the variability in the volume of the cobble, its form, its working edge, etc. In contrast, a cobble can, considered as a simple block of raw material, become the object of different modes of reduction using natural technical traits or not.

For the industries at Vale da Pedra Furada, humans chose to use cobbles to make different kinds of tools with a predetermined prehensile part already present at the selection phase and with different transformative parts, but they also chose to obtain predetermined removals on which different kinds of tools were made using a bipolar method *sensu stricto*. The diversity in working edges is such that if we combine it with variability in the blanks, we obtain a very broad range of tools for different activities: a diversity further confirmed by use-wear and techno-functional analyses. This diversity is reflected in the processing of wood, plants, bone, antler, etc. These different materials thus indicate that the stone tools are only part of a technical system including other tools made on perishable materials. Far from being archaic, these industries are the technical expression of populations with varied activities governed by precise technical rules. If the quartz cobble is the preferred raw material, this is because it perfectly meets the objectives within the technical system. How can one continue to consider these industries archaic when faced with such management of this specific raw material?

How can one speak of opportunistic reduction or shaping, or even expedient solutions? All of this is only a trap based on appearance!

6. Chronological study

a. Radiocarbon dating

Two series of radiocarbon dates have been obtained: two charcoals from the 1998 Felice test pits have been dated by Beta Analytics (Beta 119875 and Beta 11855) (Felice 2000, 2002) (Table S4). Nine other charcoals, coming from different layers and collected during the recent archaeological excavations, have been dated in the LSCE laboratory in Gif-sur-Yvette, France. For these nine charcoal samples dated by radiocarbon, sample preparation followed the acid–alkali–acid treatment: 1 M HCl, 0.1 M then 1 M NaOH 0.1 M and 1 M HCl. All treatments were performed at room temperature either in an ultrasonic bath or under agitation. Rinsing with ultra-pure water followed each step. About 1mg of clean charcoal was then sealed in a quartz tube under vacuum with an excess of copper oxide and silver wire. Tubes were introduced into a furnace at 840°C for 5 hours to transform the organic matter into CO_2. The evolved CO_2 was reduced to obtain graphite targets prepared following the method described by Arnold *et al.* (1987, 1989) and Hatté *et al.* (2003). Analyses were performed using the French National AMS facilities (LM14C) and results are expressed as conventional ages following Stuiver and Polach (1977). Calibrated ages are expressed as cal BP with a confidence level of 95.4% (2 sigma) following Stuiver and Reimer (1993) and Reimer *et al.* (2004). All the results are given in Table S4. Note that we can be very confident in the ^{14}C ages since there is no volcanic CO^2, no hard water effect and no reservoir age effect, and finally no millennial trees are known in the region. Consequently the ages can hardly have been affected by ageing, and they can be considered as very reliable.

Table S4. References, radiocarbon ages and calibrated dates of the charcoal samples.

Lab. no	Layer	Reference	Conventional age in y BP	Calibrated years BP	Calibrated years BC
SacA25553/Gif-12705	C2a/b	192487	6190±35	6912–7161	4962–5211
SacA25552/Gif-12704	C2a/b	192047	7875±40	8455–8753	6505–6803
GFD-01	C2/C3	1998 Test pit	12 700±90	14 525–15 595	12 575–13 645
SacA30854/Gif-12925	C3	198880	13 460±50	16 204–16 875	14 254–14 925

SacA30855/Gif-12926	C3	191302	13 740±60	16 695–17 044	14 745–15 094
SacA30853/Gif-12924	C4	191373	13 590±60	16 515–16 943	14 565–14 993
GFD-02	C6	1998 Test pit	18 660±260	21 502–23 220	19 552–21 270
SacA28290/Gif-12837	C7	192452	19 970±100	23 468–24 256	21 518–22 306
SacA28289/Gif-12836	C7	192455	20 070±100	23 621–24 055	21 671–22 105
SacA25554/Gif-12706	C7	192448	20 090±120	23 617–24 404	21 667–22 454
SacA30852/Gif-12923	C7	232097	19 700±100	23 198–23 913	21 248–21 963

b. luminescence dating

Some of the stratigraphic layers could not be radiocarbon dated because of the lack of organic materials. We thus decided to study the entire stratigraphy using luminescence dating techniques. Specifically, we collected one or more tube samples in each stratigraphic layer (Figure S12) to date the last exposure of the quartz grains to light.

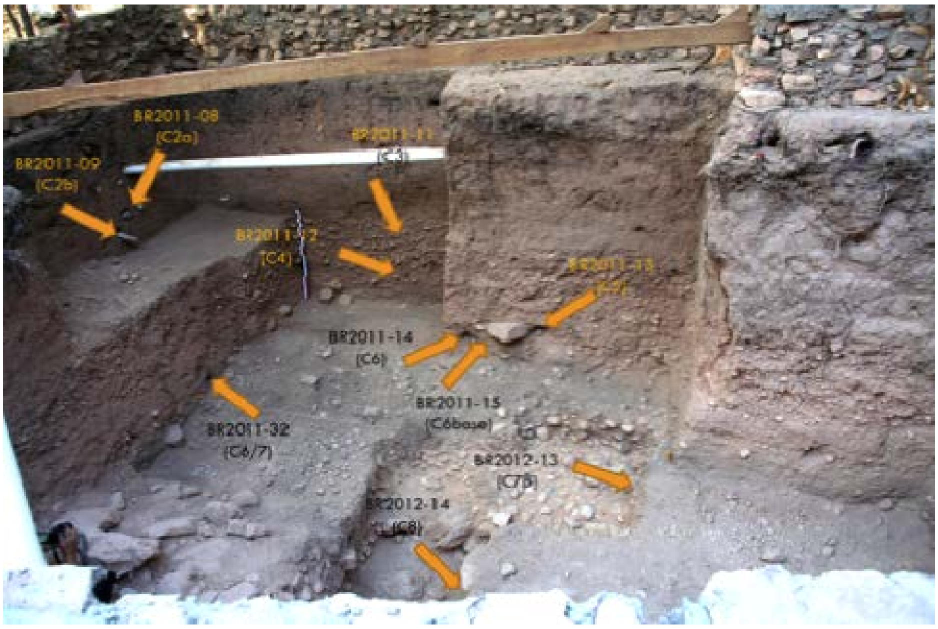

Figure S12. Location of OSL tube samples.

For OSL measurements, the sediment samples were subject to classic mechanical and chemical treatments (Wintle 1997) to extract and isolate the quartz grains from the most representative particle size fraction in the sediment. The 20–41µm fraction was selected and prepared for all samples. The equivalent doses were determined by experiments on 30–50 aliquots, using the SAR protocol (Murray & Wintle 2000, 2003; Wintle & Murray 2006). The

Central Age Model (Galbraith 1999) has been adopted (Figure S13). The De values measured, as well as the overdispersion values, are presented in Table S5.

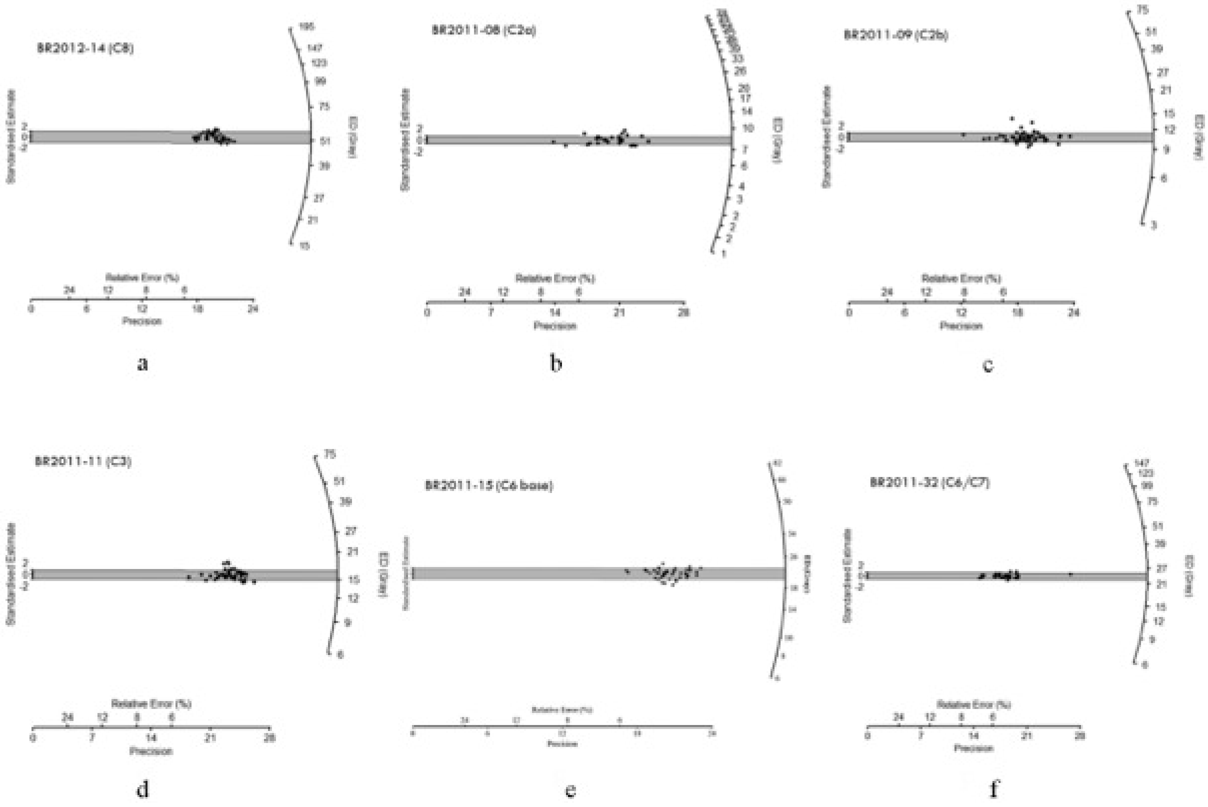

Figure S13. a–f) Radial plots of multiple grains D_e values. In all cases a single-component D_e distribution is observed and the Central Age Model has been adopted. The grey lines denote the 2σ (95% confidence interval) bounds on the reference value.

Annual dose rates were measured for each sediment sample, both by *in situ* measurements (LaBr Gamma-spectrometry) and by laboratory measurements in the IRAMAT-CRP2A in Université Bordeaux 3, France (High Purity Low Background Germanium ‘well-shaped’ gamma spectrometer). Complementary measurements have been conducted to determine the K, U, and Th contents of the grains, thanks to ICP-MS measurements in the LSCE in Gif-sur-Yvette , France. The results are presented in Table S5. Based on these measurements we have determined the annual dose rate rates, both internal and external, and the ages of the samples. The results of the chronology study are presented in Figure S14.

Table S5. Radiometric data and OSL ages of the sediment samples from the Vale da Pedra Furada archaeological site.

		Sediment			Quartz grains								
Sample code	Level	K (%)	U (ppm)	Th (ppm)	K (%)	U (ppm)	Th (ppm)	Internal dose rate (µGy/a)	External dose rate (µGy/a)	Total dose rate (µGy/a)	De (Gy)	OD (%)	Date (years BC)
BR2011-08	C2a	0.08±0.01	0.85±0.03	6.37±0.01	0.322±0.017	2.08±0.02	12.12±0.12	280.7±51.5	862.0±26.9	1142.7±58.1	8.5±0.2	10.2±1.7	5500±800
BR2011-09	C2b	0.08±0.01	0.96±0.02	7.05±0.07	0.363±0 019	2.00±0.06	12.94±0.06	288.1±53.3	895.8±28.3	1183.9±60.4	10.8±0.2	11.5±1.4	7100±1000
BR2011-11	C3	0.03±0.01	0.31±0.02	2.39±0.05	0.294±0.015	2.22±0.02	6.46±0.16	210.1±38.4	612.9±16.4	823.1±41.8	16.0±0.2	8.0±1.1	17 500±2000
BR2011-12	C4	0.07±0.01	0.78±0.02	5.44±0.08	0.013±0 001	1.80±0.01	4.09±0.08	152.6±28.9	810.6±24.0	963.3±37.6	18.0±0.2	4.7±0.9	16 700±1700
BR2011-13	C5	0.03±0.01	0.32±0.01	2.32±0.05	0.012±0.001	2.53±0.05	5.68±0.24	213.5±40.7	609.1±16.3	822.6±43.9	18.6±0.2	5.1±1.1	20 600±2400
BR2011-14	C6	0.05±0.01	0.59±0.02	4.11±0.06	0.015±0.001	1.96±0.06	4.37±0.12	165.0±31.5	609.5±19.0	774.6±36.8	21.4±0.3	6.7±1.2	25 600±2800
BR2011-15	C6base	0.06±0.01	0.76±0.02	5.26±0.06	0.026±0.002	1.97±0.10	8.32±0.46	216.6±39.8	677.1±22.2	893.8±45.6	21.2±0.3	6.7±0.9	21 700±2600
BR2011-32	C6/C7	0.08±0.01	0.95±0.02	6.21±0.08	0.398±0.021	2.42±0.08	10.43±0.18	276.3±50.0	747.5±24.2	1023.9±53.5	24.0±0.3	3.4±1.4	21 400±2800
BR2012-13	C7b	0.06±0.01	0.71±0.02	5.61±0.09	0.012±0.001	2.15±0.05	4.39±0.17	175.4±33.8	676.2±22.2	851.7±40.5	22.6±0.4	6.0±1.4	24 500±2800
BR2012-14	C8	0.09±0.01	1.09±0.02	9.61±0.09	0.024±0.002	2.49±0.08	6.38±0.27	220.3±41.5	1177.3±33.3	1397.7±53.3	53.7±0.5	4.4±1.1	36 400±3600

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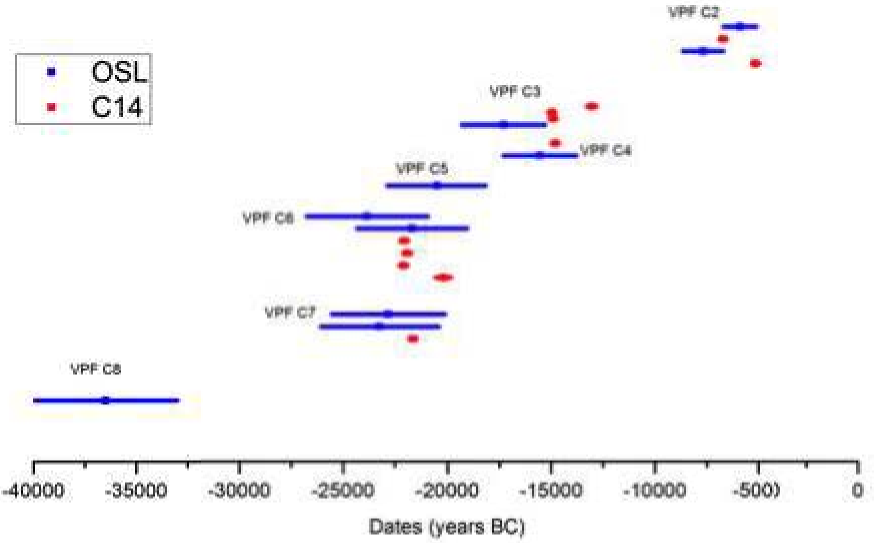

Figure S14. Chronology of the Vale da Pedra Furada occupations: summary of OSL dates (years BC) in blue and radiocarbon dates (cal years BC) in red.

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